

Lunar Exploration Analysis Group (LEAG)

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Lunar Exploration Analysis Group

- Community based, interdisciplinary forum
- Analyzes scientific, engineering, technology, and operational issues associated with lunar exploration to support the Vision for Space Exploration—i.e., it asks tactical questions
- Reports findings and analysis to Science Mission Directorate and Exploration Systems Mission Directorate, through NASA Chief Scientist

Goals for First Meeting

(Meeting Held January 10-12, 2005)

- Hear status reports on science, technology, human exploration, robotic exploration, LRO, and planned international robotic lunar missions
- Analyze two important questions:
 1. What will humans do on the Moon when they get there?
 2. What are the priorities and phasing for human precursor investigations and technology
- Plan next steps for LEAG
 - Specific Action Teams
 - Plan preliminary agenda for next meeting
 - Outline subsequent meetings

Major Findings

- Assumption: sustained human presence on the Moon is essential for a dynamic program of robotic and human exploration of the solar system
- Importance of In Situ Resource Utilization
- Exciting set of human activities identified
- Measurements, experiments, and other activities for robotic missions identified and rough priorities established
- Need a scientific instrumentation/facility development program

Sustained Human Presence

- Strong consensus that lunar program should lead to continuing expansion of human capabilities on the Moon
 - Learn how to live and work on another planet, essential for the human exploration of Mars and beyond
 - Allows for increasing involvement of private sector as capabilities of transportation system and lunar facility increase

Sustained Human Presence-2

- Strong consensus that program should focus on one locality that serves as a focal point for human exploration
- Advantages of single site:
 - Leads to incremental growth of the facility and its capabilities
 - Opens the way for a permanent facility that allows permanent habitation
 - Its evolutionary development and long-term operation require developing capabilities for self-sustaining operation (e.g., ISRU, closed system life support)

Sustained Human Presence-3

- Advantages (continued)
 - Develops capabilities for doing long-duration missions to Mars and beyond
 - Allows for long-duration science studies (e.g. biological medical studies, certain geoscience investigations)
 - Allows for in-depth science study of one site
 - Lends itself to developing a strategy for transition from government to private operation
 - Becomes an off-Earth village in public perception

Sustained Human Presence-4

- Disadvantages of single site:
 - Limit the number of diverse terrains studied (at least until capability for global access established)
 - Limited types of ISRU experiments
 - We may not know by 2015 where to establish the base, so it is wise to keep open the option of going to multiple landing sites for reconnaissance
 - More difficult to do global network science (e.g., seismic network to study lunar interior)
 - May need to go to more sites to meet overall mission needs (e.g., resources, experiments in human habitation out of sight of Earth)

Sustained Human Presence-5

- Disadvantages of single site (continued)
 - Danger of bureaucratic fixation of big lunar base and then maintaining it without end. Mitigated by
 - Involvement with private industry from the start
 - A strategy to transition to non-NASA operation
 - Plans to lease facilities to or from private enterprises
- Possible Modification to Single Site Approach
 - Maintain Spiral 2 as consisting of multiple reconnaissance missions to multiple location
 - Consider one location for spiral 3, for buildup of infrastructure and capabilities. Capabilities include maintaining excursion abilities to other locations

Importance of In Situ Resource Utilization

- Strong consensus that ISRU is necessary for sustainable (including affordable) human presence in space.
- Experiments on robotic and human missions needed (priority order based on timing)
 - How to move and handle regolith
 - Thermal processing of regolith (e.g., sinter to make pavement)
 - Resource extraction (e.g., oxygen via reduction of regolith, extraction of ice)

A Guiding Principle of Exploration

- Consensus that the robotic and human mission set should do the following:
 - 1) Improve human exploration capabilities, including cislunar space and Mars (e.g., production of propellant)—I.e., Contribute to sustained human presence on the Moon to enable exploration beyond
 - 2) Fundamental science (geoscience, space physics, astronomy, biology, human biology, materials science, etc.)
 - 3) Experiment and innovate potential commercial and industrial applications, with private industry involvement

Robotic Measurements, Experiments, and Other Activities

- Prime objectives:
 - Resource assessment and development
 - Human safety during long-duration stays on Moon
 - Characterization of potential human mission landing sites
 - Science studies

Robotic Measurements, Experiments, and Other Activities

- Elements of robotic missions--higher priority
 - **Resource assessment (prospecting, esp. polar regions)**
 - **Experiments on regolith excavation and handling**
 - **Experiments in resource extraction and storage**
 - **Biology experiments**
 - **Baseline scientific characterization (before extensive contaminated or altered)**
 - Lunar atmosphere characterization
 - Read the scientific record of the polar volatile deposits
 - **Emplacement of infrastructure elements**
 - Modest at first (comm/nav, landing beacon)
 - Increasingly more complex with time

Robotic Measurements, Experiments, and Other Activities

- Elements of robotic missions--lower priority because they can be done later
 - Behavior of fluids at 1/6 g (ISRU, biology, closed-loop systems)
 - Dust:
 - Aerosol physics
 - Characteristics, inhalation hazard, charge state, chemical hazard, 1/6 g effects, settling/dispersion rates
 - In situ particle characterization
 - Radiation dosimetry
 - Installation of seismometers and other network science instruments
 - Gas content of undisturbed lunar regolith
- Set of orbital measurements not being done by LRO (lower priority on requirements list set forth by ORDT)

Technology Demonstrations

- Excavation, material handling, workability of regolith (early in program, high priority)
- ISRU process validation (early, high)
 - Extraction of volatiles
 - Extraction of oxygen from the regolith
- Closed loop life support system, storage of waste (early, high)
- Precision landing, hazard avoidance, hazard tolerance (early, high)
- Material processing for fabrication and construction (late, medium)
- Telerobotic experiments (early, high)
- Robotic sample collection (late, medium)
- Space weathering of materials (old hardware) (late, lower)

Robotic Mission Landing Sites

- Priority given to characterizing permanently shadowed site at lunar poles
 - Importance of polar regions
 - Ice (if it is there) is an important resource
 - Cold traps themselves might be a resource (e.g., IR telescope)
 - Places with nearly permanent illumination:
 - Might eliminate need for nuclear power
 - “Permanently” illuminated areas are more like Mars than any other place on Moon
 - Scientific value of cold traps is very high
 - Cold regions most like environments in outer solar system (icy satellites, comets, Kuiper belt objects)—the Moon, Mars, *and beyond*

Robotic Mission Landing Sites

- First landed robotic mission does not necessarily need to land in permanently shadowed location
 - May need time to assess LRO data to choose site
 - Excellent technical and scientific studies can be made in illuminated area
 - Could even land a mission in an equatorial region (e.g., on a volcanic deposit) to test systems, do biology and other experiments, and an ISRU demonstration

Other Important Matters

- Strong consensus that we need for a program to develop scientific instrumentation and facilities
- Need for private involvement from the start, including on robotic missions. (Not enough discussion to know if this is a consensus view.)

Possibilities:

- Prizes
- Data purchases
- NASA-industry partnerships on instrument or ISRU experiment

Action Items

- Identified need for Specific Action Teams (details still being decided):
 1. Goals Committee to establish goals, objectives, activities/measurements, and priorities for lunar exploration, including goals for lunar science
 2. Science Instrumentation and Facilities Team to define a development program in biotechnology, geoscience, materials science, and other science

Action Items

3. Analytical Lab/Sample Return Analysis Team

- Trade off between sample mass (geological, biological, materials science), sophistication of lunar surface analytical facilities, and time spent by astronauts
- Analytical devices needed in the field vs laboratory
- Trade off between in situ analysis and return of samples that are difficult to preserve (e.g., ice-bearing regolith at 50K)

4. ISRU options, strategies, and priorities

- ISRU and its role in permanent human presence on planetary surfaces
- What constitutes a “resource”
- How do we characterize resources?

Action Items

- Specific Action Teams 2–4 will complete their studies by the next meeting (June 2005)
 - Present their findings
 - Discussion among participants to modify and reach a consensus
- Goals Committee will begin the process, with input from the strategic roadmapping activity
 - Discussion of goals in breakout groups during next meeting
 - Implies that the basic structure has been developed by June 2005

Next Meetings and Their Objectives

- Next meeting, June 2005:
 - Same invited group (possibly slightly supplemented) as for first meeting
 - Discuss and reach consensus on output from SATs 2–4
 - Discussion of Goals, objectives, etc.
 - Breakout group that examines the role of LRO in providing guidance for site selection for polar lander
 - What key information LRO provides
 - When derived results will be available
 - An assessment of the number of landing sites or extent of mobility needed to characterize polar deposits
 - Assessment of hard vs soft landers
 - May evolve into a Specific Action Team

Next Meetings and Their Objectives

- June 2005 meeting (continued)
 - Breakout group to make a quantitative assessment of ISRU based on work done by SAT
- Fall 2005
 - All hands meeting
 - Something of a conference, but with emphasis on useful products, such as these examples:
 - **Roles of government and private sector**
 - Detailed look at potential testbed payloads for ISRU